Compton Polarimeter

Anna Micherdzinska
University of Winnipeg
for Hall C Compton Polarimeter group

Outline

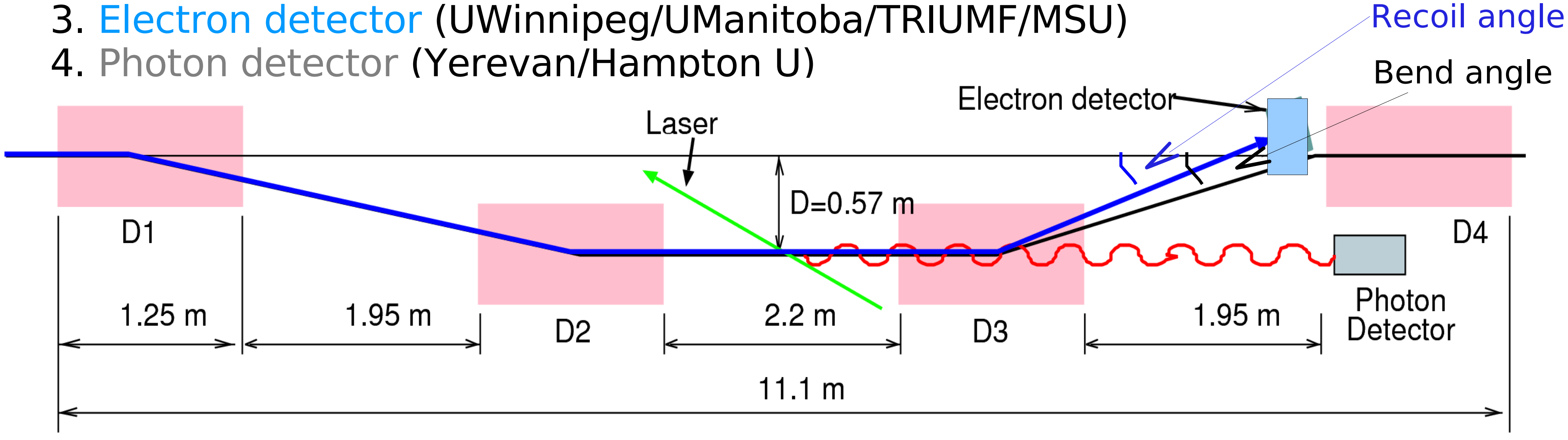
1. Motivation of project
2. Updates on Compton subsystems:
    1. Magnetic Chicane
    2. Laser beam
    3. Photon detector
    4. Electron detector
3. Summary (Milestones)

Motivation of Compton polarimetry in Hall C

1. Q_{WEAK} requires to measure beam polarization to 1%
2. Required to make continuous beam polarization measurement at same time as data-taking (non-invasive measurement !).
3. Provide cross-check of Hall C Moller
4. Compton should be easy to upgrade to 12GeV

Requirements:

1. Insertion of a 11m dipole chicane in Hall C (MIT)
2. Laser (The Polarized Source Group/UVa)
3. Electron detector (UWinnipeg/UManitoba/TRIUMF/MSU)
4. Photon detector (Yerevan/Hampton U)



side view of dipole chicane

Compton Working Group: January 15, 2008

Room F326, 1:30 P.M.

13:30	Welcome and Overview	(15)	D. Gaskell
13:45	Hall C Beamline re-design	(15+5)	B. Dillon-Townes
14:05	Compton Dipole Design	(20+5)	E. Ihloff
14:30	Compton Laser Update	(20+5)	M. Poelker
14:55	Break	(25)	
15:20	Laser Frequency Doubling and External Cavity	(25+5)	S. Zhang
15:50	Electron Detector	(20+5)	D. Dutta
16:15	Electron Detector	(15+5)	A. Micherdzinska
16:35	Interaction Region (discussion)	(30-40)	K. Paschke
17:10	Data Acquisition (discussion)	(30-40)	All

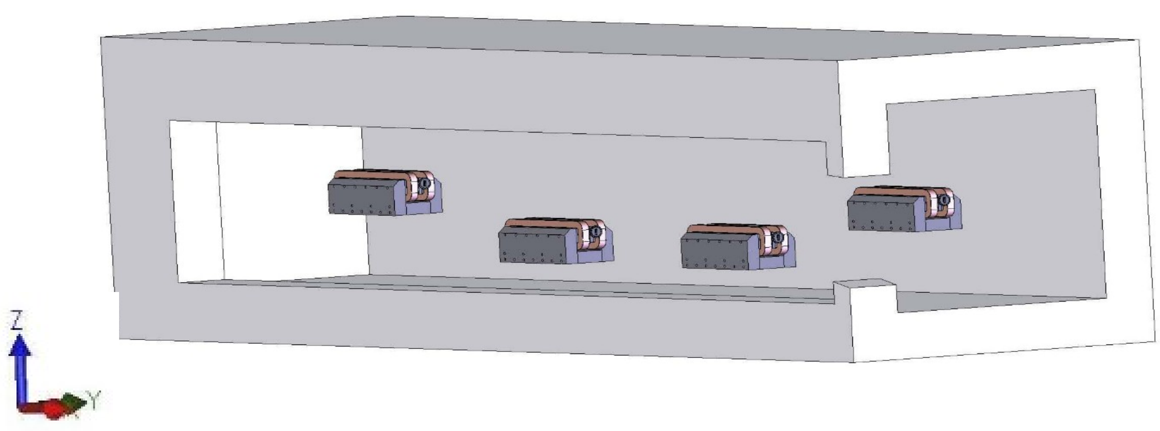
Hall C Compton chicane design requirements

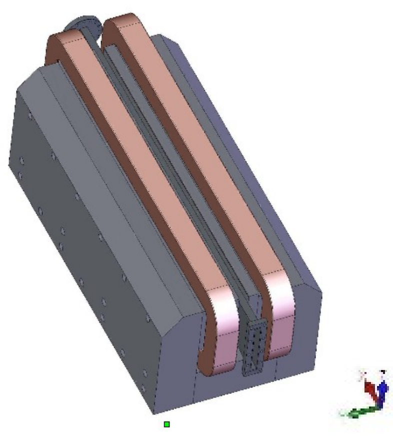
(MIT: Ernie Ihloff, Jan van der Laan)

- Compton magnets
- High vacuum system that meets Compton levels
- Support stands that allow movement
- Total integration into existing tunnels

Basic design:

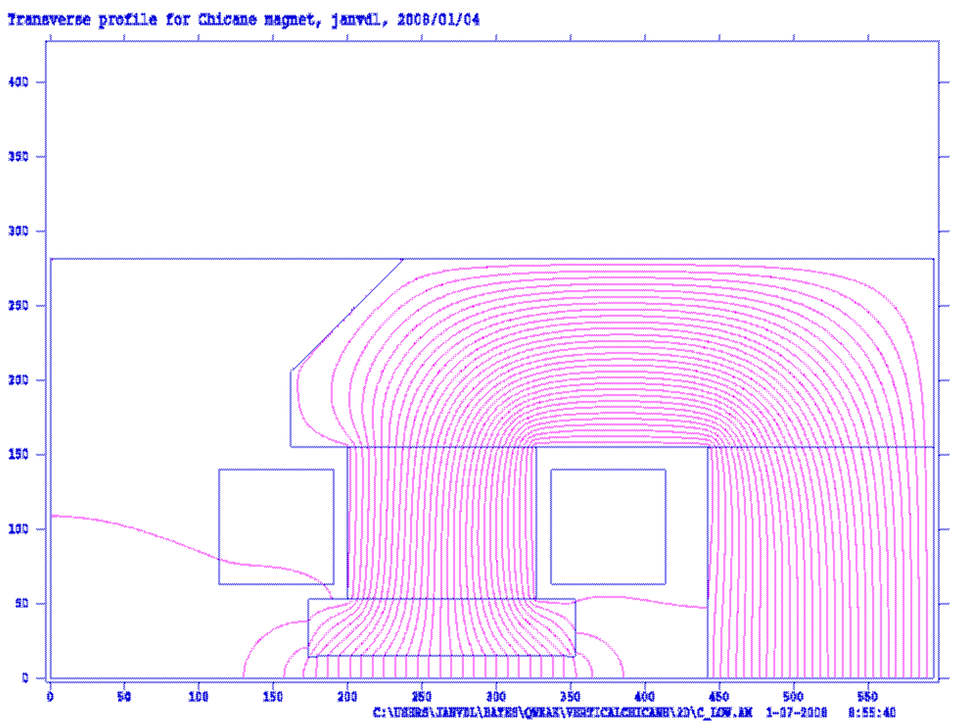
- At 13 cm offset, 11.023 GeV, 12.14 kG and 2.4 degree Bend
- At 57 cm Offset, 1.165 GeV, 5.58 kG and 10.3 degree Bend



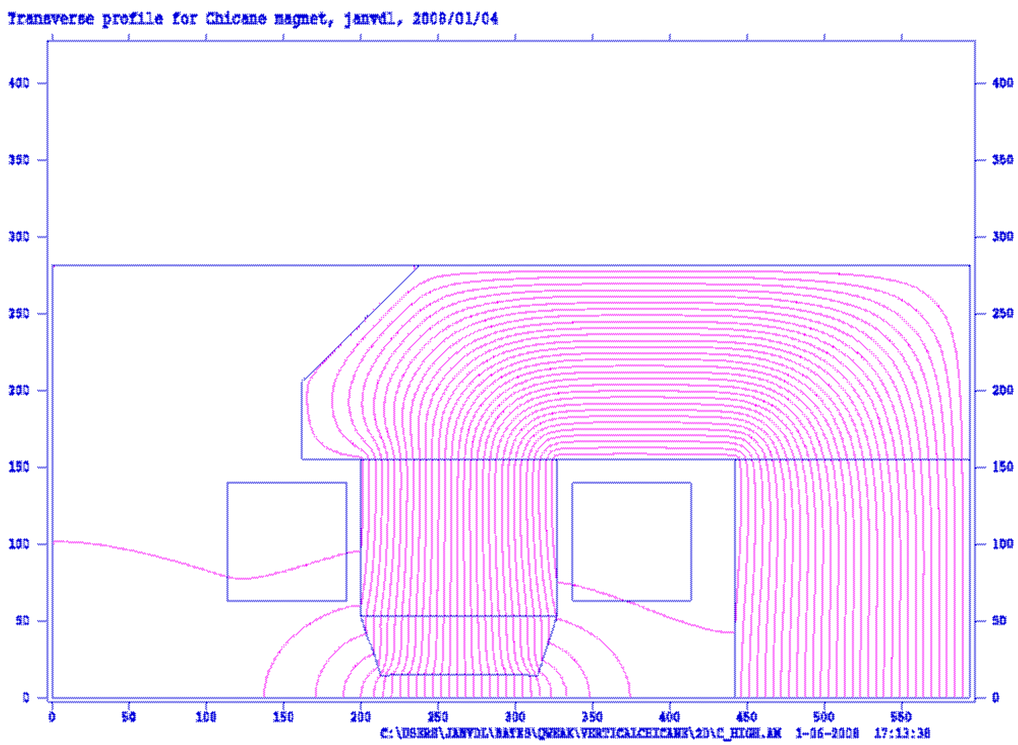


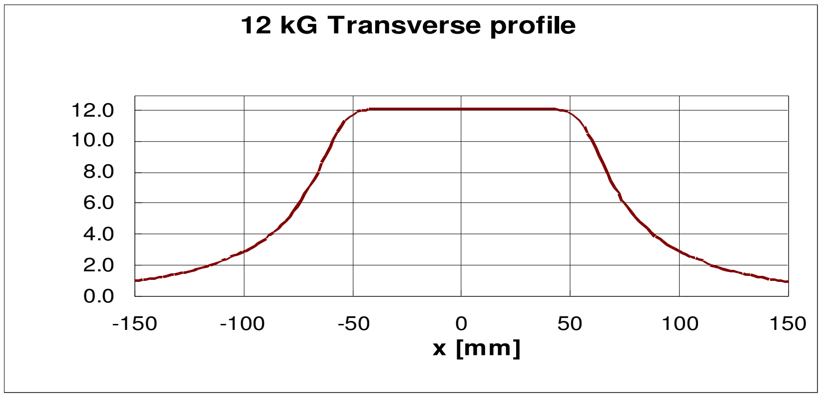
Calculating Transverse Magnetic field

5.5 kG



12 kG





Schedule to complete magnetic chicane (from Ernie Iloff MIT)

- Magnet details complete by 1 March 2008
- Fabrication by October 2008
- Support stand Vacuum system done by same time
- Ready to measure by Nov 2008

Laser beam

(The Polarized Source Group/UVa)

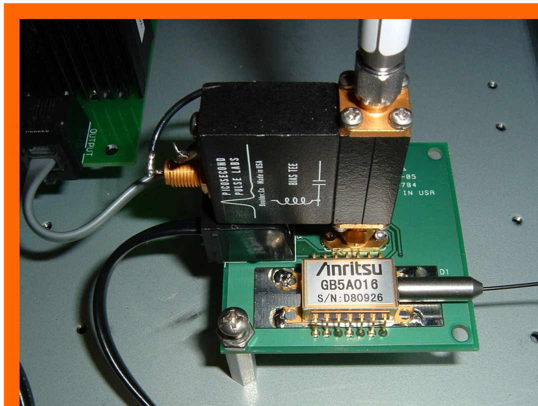
- Matt Poelker proposed a fiber laser option with:
  - Modest average power: 20W (532 nm)
  - Pulse width ~30ps at 499 MHz
  - Optical properties: M^2=1.33
- This system uses:
  - **seed laser** (1064nm), **fiber amplifier** (50W output at 1064nm), **frequency doubling cavity**
- Average power from fiber laser modest (20W). For laser pulsed at electron beam repetition rate (499MHz) and comparable pulse width (on the order of ps), the luminosity is increased by a factor:

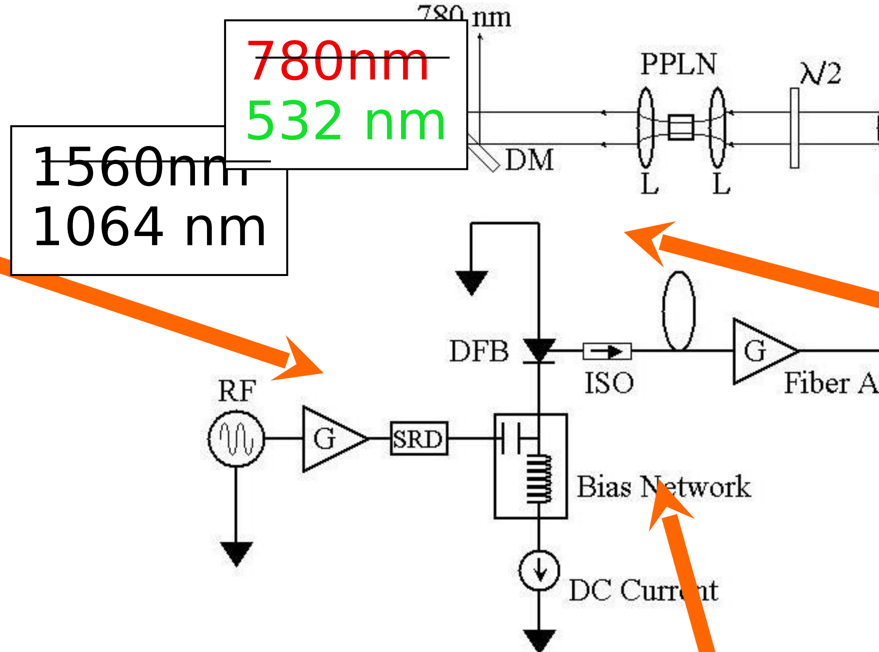
$$\frac{L_{pulsed}}{L_{CW}} \approx \frac{c}{f\sqrt{2\pi}} \left(\sqrt{\sigma^2_{c\tau,laser} + \sigma^2_{c\tau,e} + \frac{1}{\sin^2(\alpha/2)} \left(\sigma_e^2 + \sigma_{laser}^2 \right)} \right)^{-1}$$

for typical Jlab parameters this leasd to a factor of 20 improvement in luminosity (for α=20mrad)

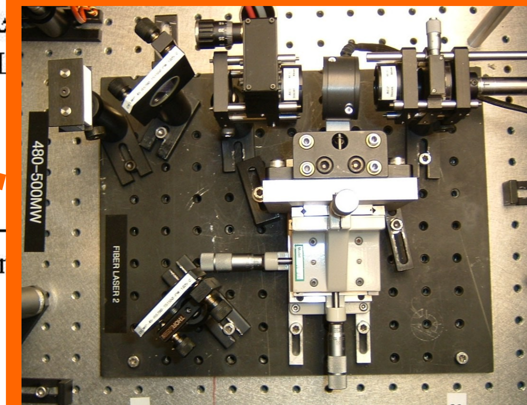
Fiber-Based Drive Laser

Gain-switched seed





Frequency-doubler

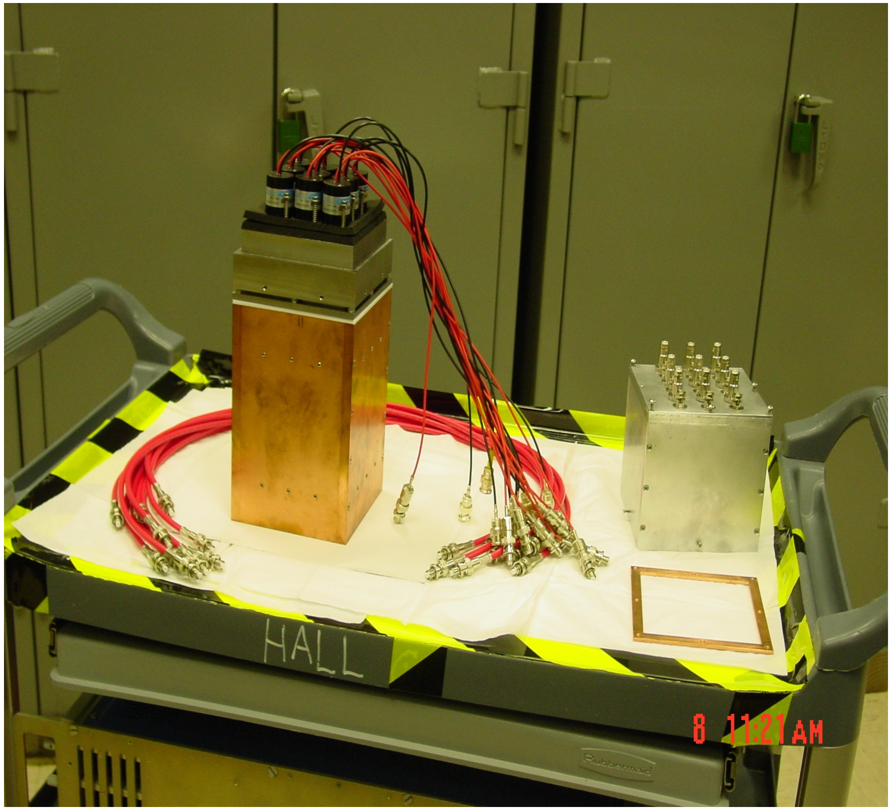


ErYb-doped fiber amplifier

Summary of Laser Progress

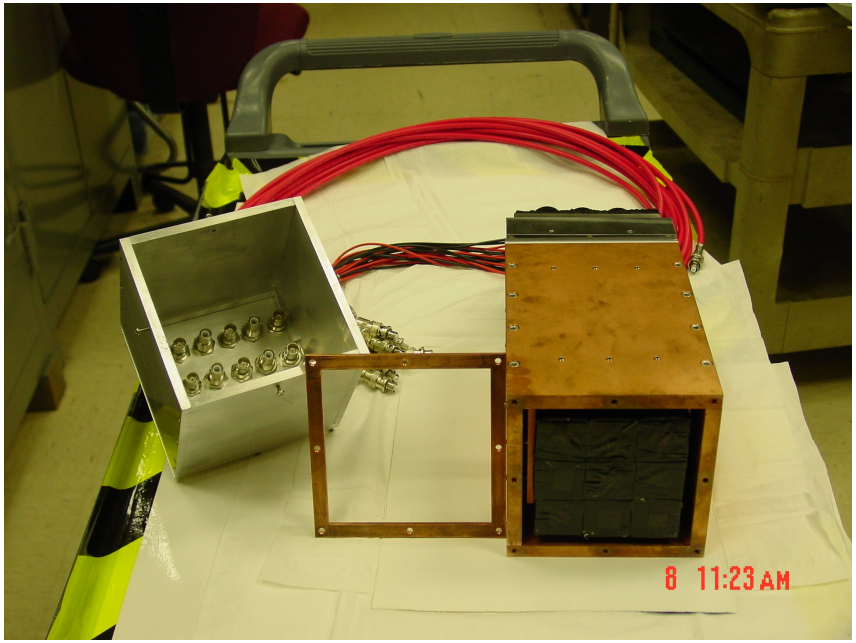
- Polarized source group will build this laser (with help from Shukui Zhang from FEL for the frequency doubling)
- Waiting for fiber amplifier (delivery was expected Nov. 2007)
- We may not run at 499MHz but 1/4 (125MHz) -> doubling efficiency vs repetition rate
    - IR50W/500MHz,   30% effi, 15W/SHG
    - IR50W/1000MHz, 14% effi, 7W/SHG
- Use of the low power external cavity will be investigated (like Hall A has, but more modest – low gain cavity)

Photon detector (Yerevan/HamiltonU)



→9 block lead-tungstate detector
→Not necessarily optimized for Q_{weak}
→Originally intention was for 1-6 GeV use

Prototype has been tested in SOS,
but pion backgrounds made it
difficult to precisely map out response

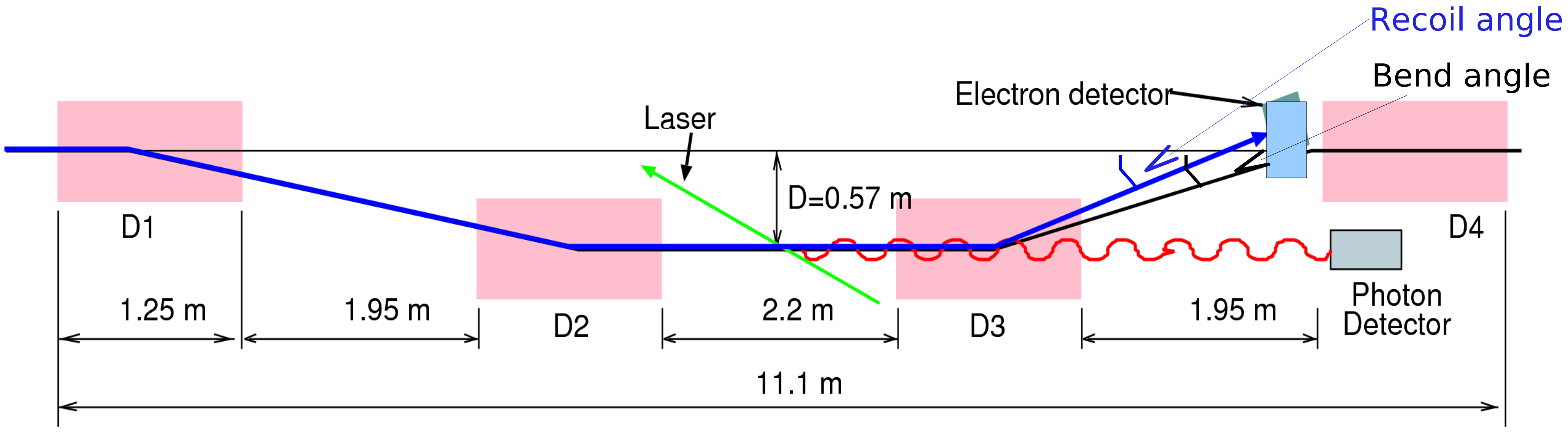


Disadvantage – low resolution
Solution: to use other kind of crystal
good for 1 GeV (was discussed during
Qweak meeting)

Electron detector

(UWinnipeg/UManitoba/TRIUMF/MSU)

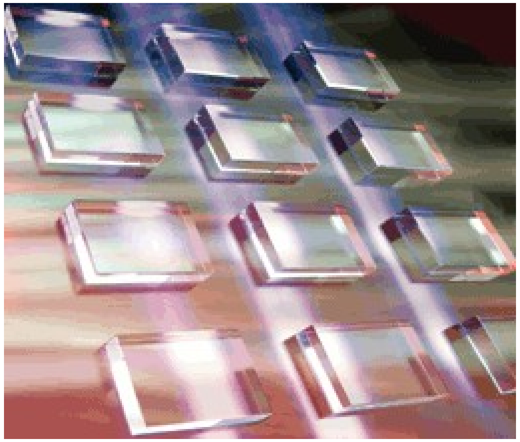
- Position resolution gives momentum of scattered electron (4x100 strips – for momentum analysis)
- Independent single-arm measurement of polarization
- Design for 1% polarization determination
- Using diamond as e- detector



side view of dipole chicane

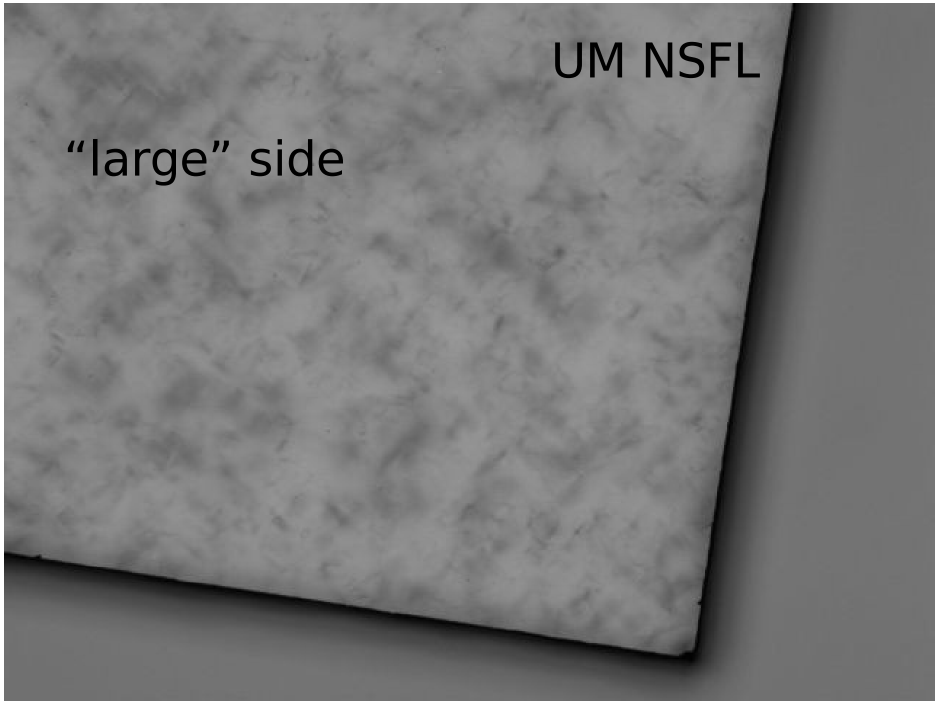
Diamond fabrication process

Step1: Purchase 'CERN grade" diamond from elementsix ADVANCING DIAMOND



UWinnipeg (Jeff. Martin) and
MSU (Dipangkar. Dutta) each ordered:

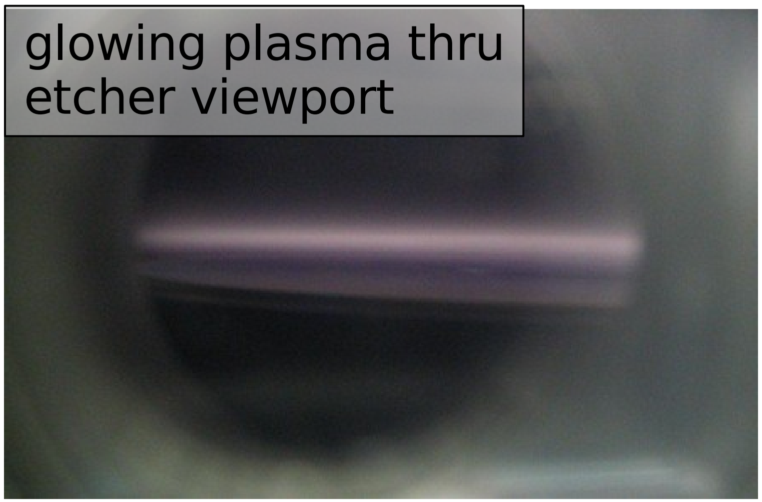
10mm x 10mm x 500um PC-CVD

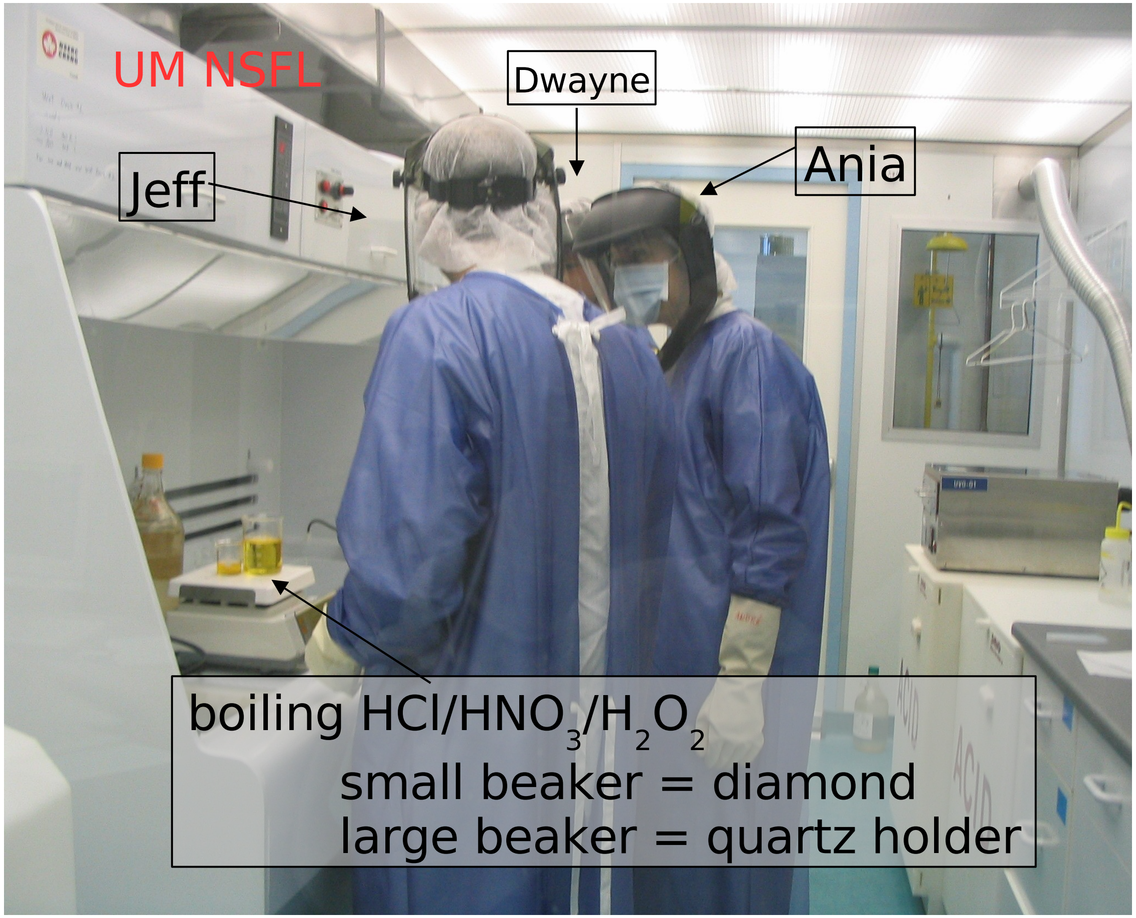


Diamond fabrication process

Step2: Boil in various acids/bases.

- cleans off the surface
- attempt to replace H-terminated surface with O-terminated (oxidizing agents like H_2O_2)
- follow with low-power plasma etch in O_2 environment

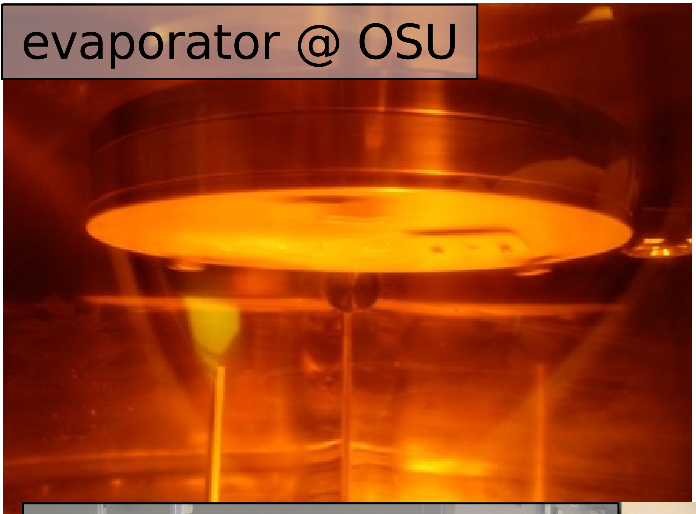


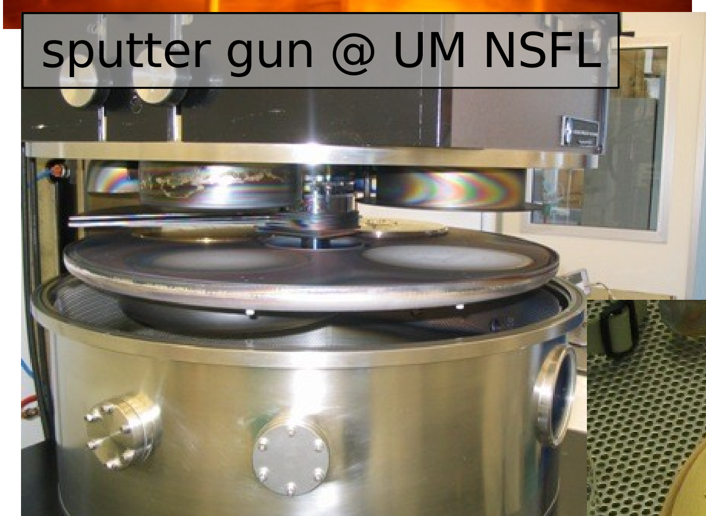


Diamond fabrication process

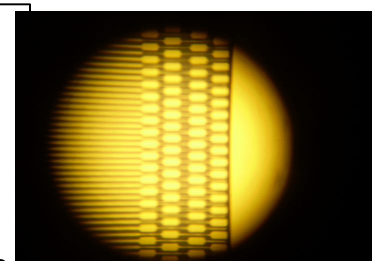
Step3: Lay down metal

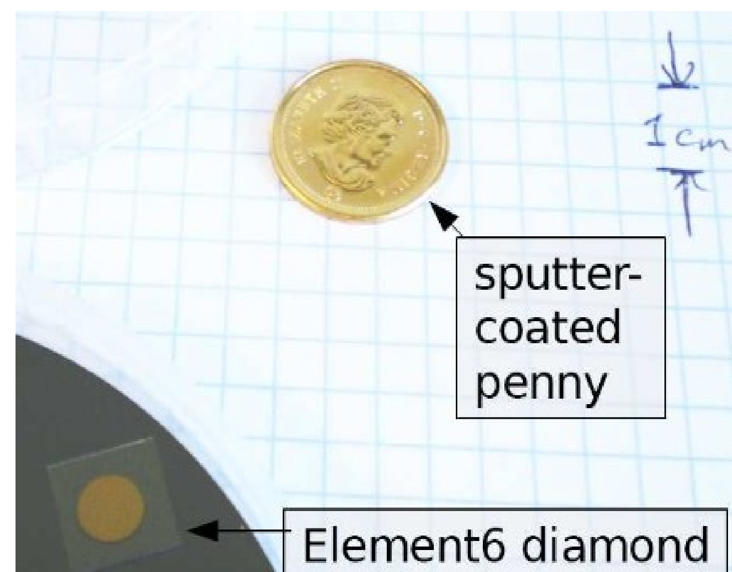
- sputter or evaporate
- test detectors usually done with Cr (50 nm) / Au (200 nm)
- shadow mask used for “dots”
- photolithography (“lift-off”) used for strips.
- OSU procedure: dots, then strips, for <u>every</u> diamond.





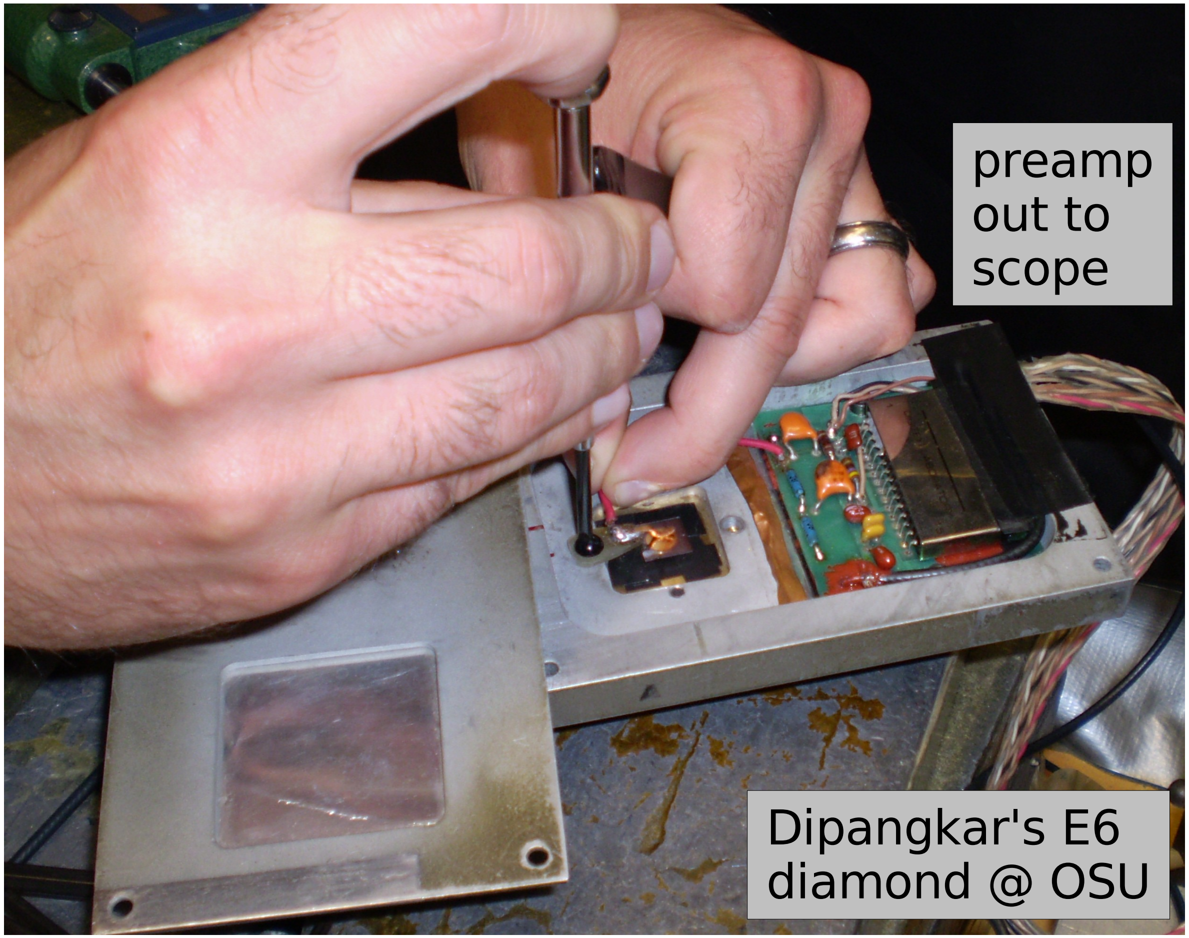
strips on glass @ OSU 50 um pitch

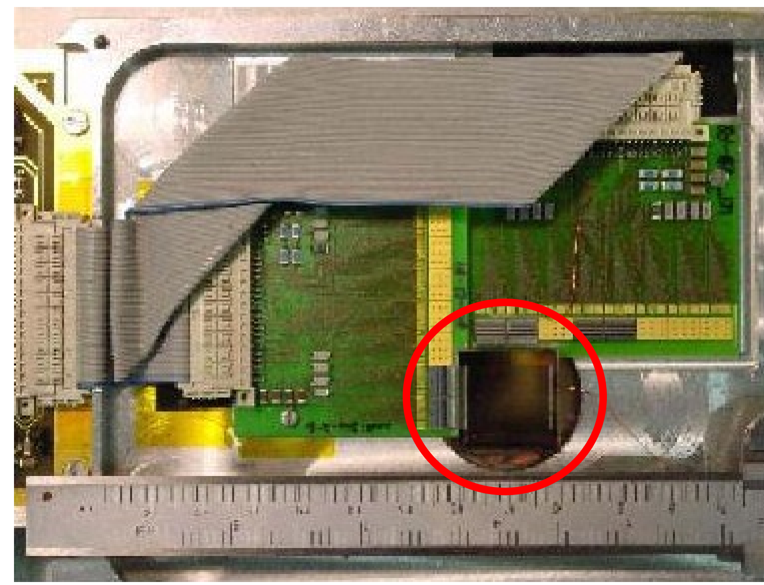




Diamond fabrication process

Step4: Test / mount in package



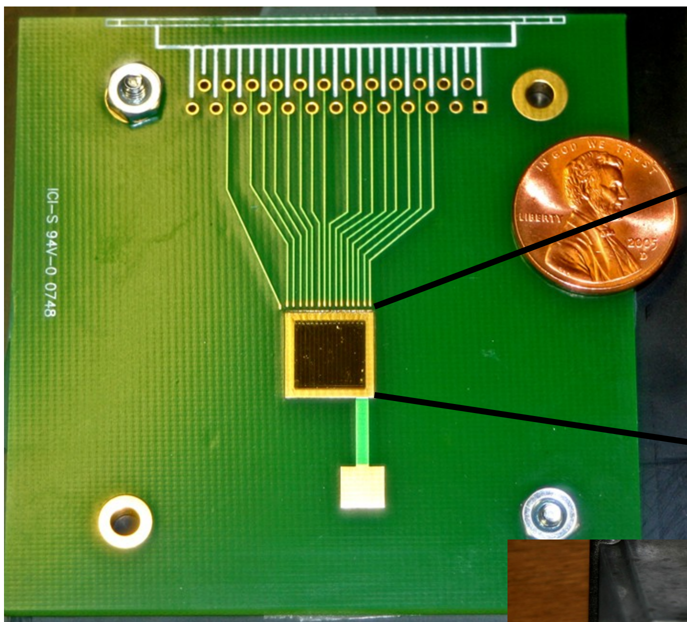


RD42-owned diamond strip tracker with seven planes, 50 um strip pitch.

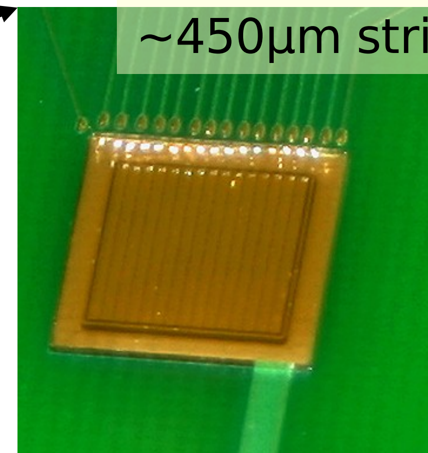
A Prototype Diamond Strip Detector

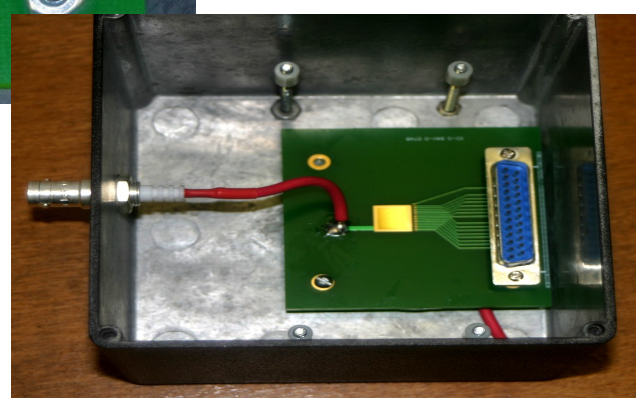
10x10 mm² detector (CERN) grade diamond from Element 6

Metalization and Lithography (15 strips ~450µ wide) at High Energy Physics Lab at Ohio State University
(Thanks Prof. Harris Kagan and his group at OSU).



Diamond with 15 strips
~450µm strip pitch



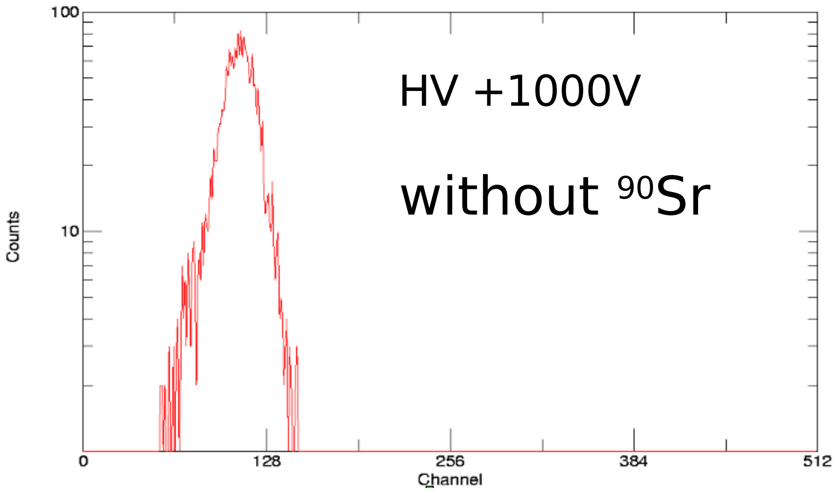


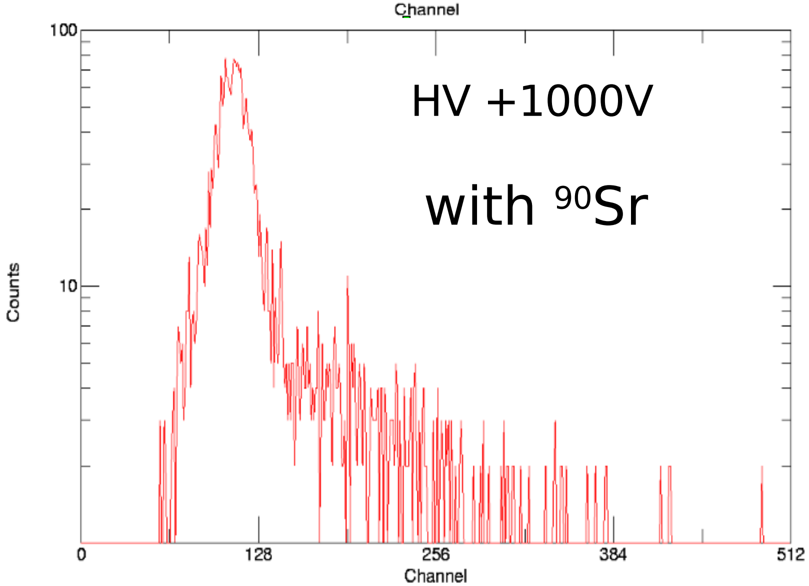
Detector enclosure

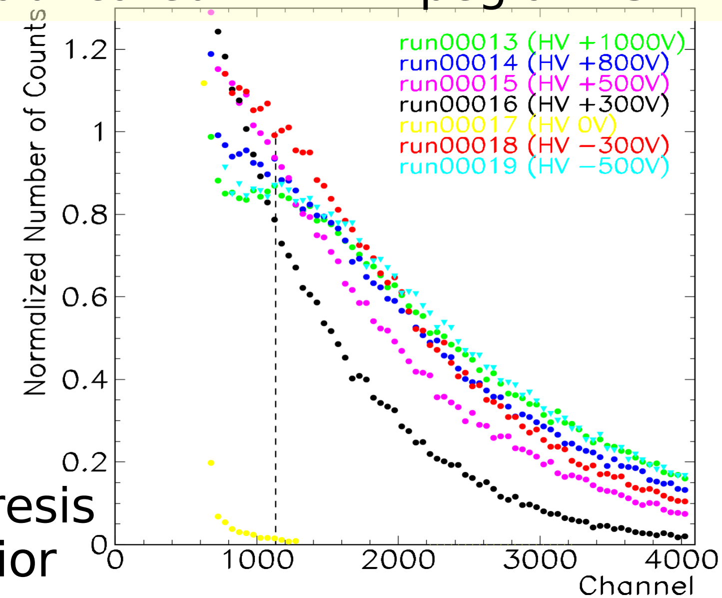
Test results with 90Sr source

Cr/Au 6 mm dot on both sides of diamond fabricated in Winnipeg at NSFL

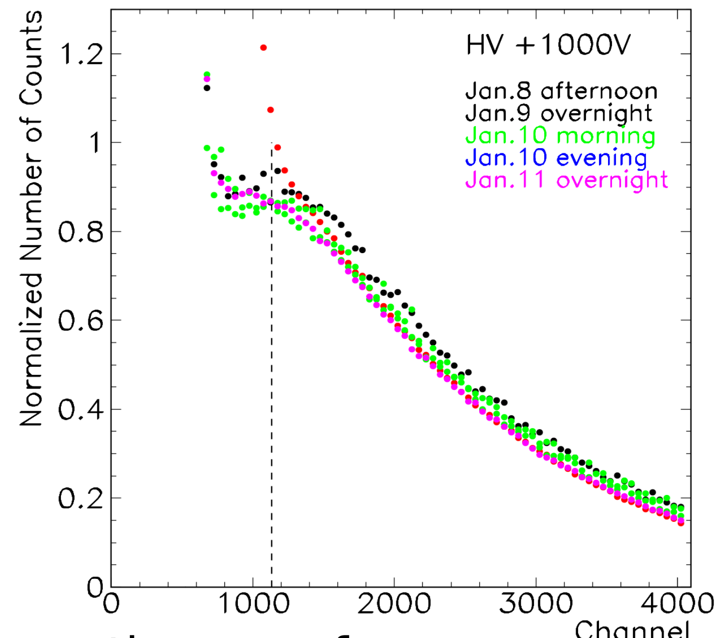
Cr/Au one strip, fabricated at OSU, tested at MSU







Hysteresis behavior

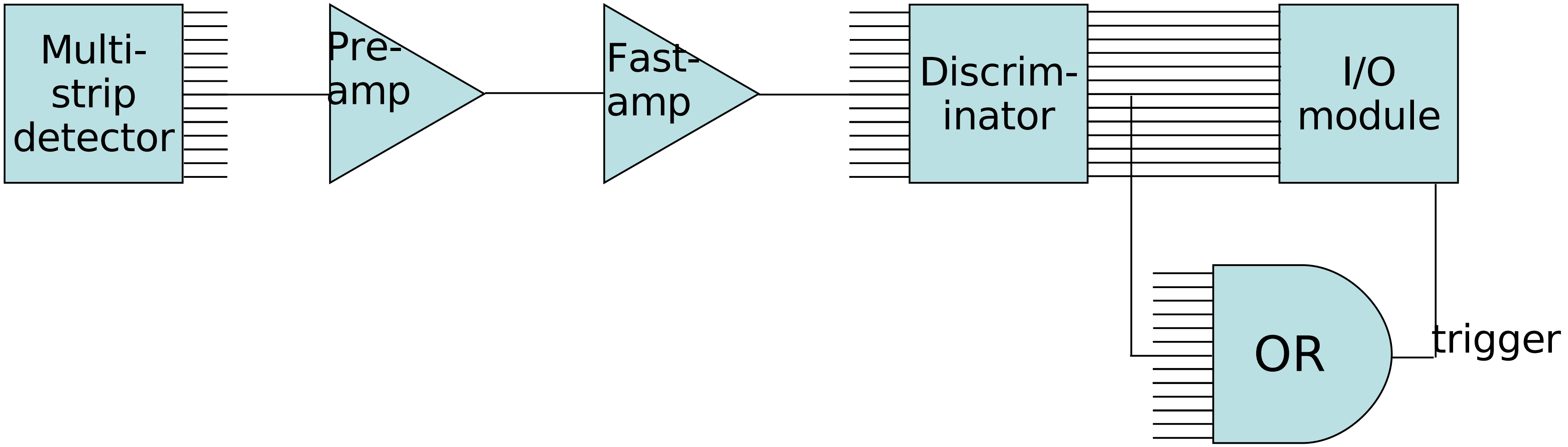


Stable operation over few days for the +1000 V

e- detector electronics

- preamp, discriminator, input module chain

For 400 channels (4 planes with 100 strip each)

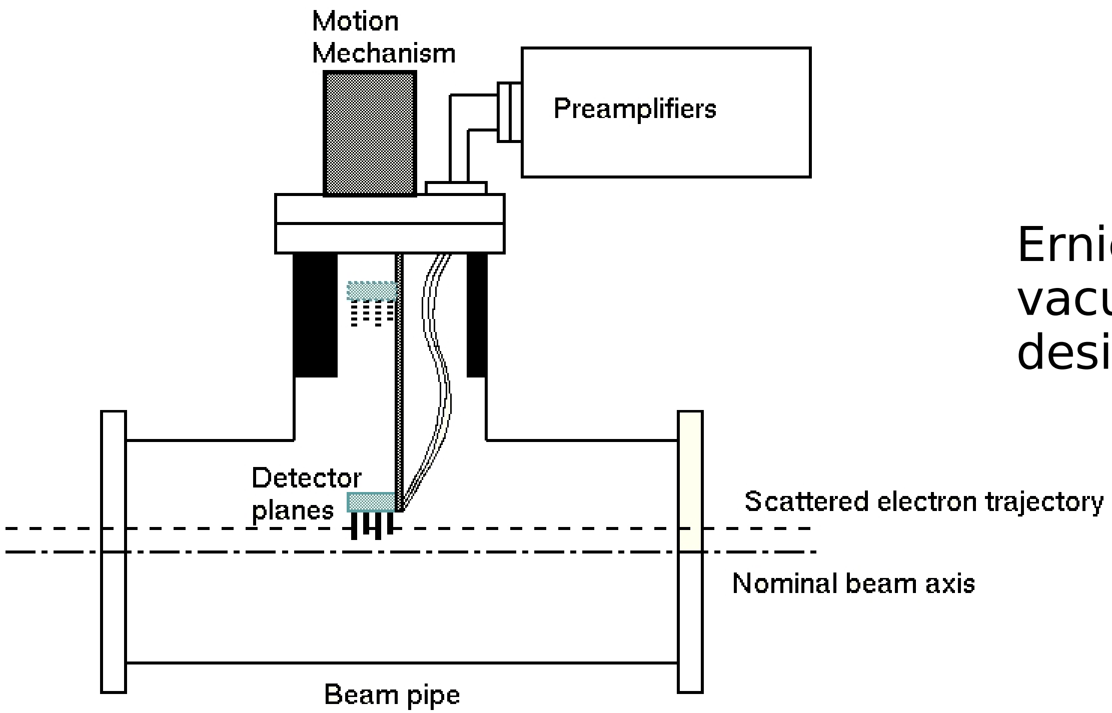


Requirements:

- 4 x 100 strips – for momentum analysis
- Fast – high rates (~100kHz) expected from Compton Scattering + background
- High Amplification – small signal in diamond, ~ 1/4 silicon

e- detector mechanics

Pipe, motion mechanism feedthroughts good for UHVacuum



Ernie Ihloff will help with
vacuum chamber
design (no instrumentation inside)

We submitted new grant for mechanics and spare spare complete diamond strip tracker (catastrophic beam event) diamond (will know answer on April 1)

Electron detector summary

- New e- detector Compton is being developed for Hall C
- Detector will be <u>installed in 2009</u>
- Detector will be used for 12 GeV as well

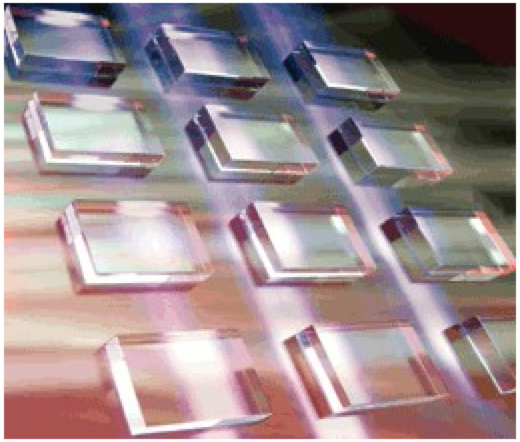
Compton Milestones

Task	Responsible Institutions	Planned Completion Date
Dipole magnet details	MIT-Bates	March 2008
Finalize chicane	MIT-Bates	**October 2008**
Photon detector tests	Yerevan/HU	April 2008
Photon detector final construction	Yerevan/HU	**January 2009**
Fiber laser low power prototype	JLab/UVa	March 2008
Final laser choice	JLab/UVa	March 2008
Laser transport setup	JLab/Uva	July 2008
Electron detector fabrication	Winn./Man./TRIUMF/ Miss.St.	October 2008
Compton Installation	JLab	**Spring 2009**

Extra

Bought “CERN grade diamonds from

elementsix™
ADVANCING DIAMOND



Chemical Vapour Deposition (CVD) - method of diamond synthesis that can be compared to frost forming on a window – only the process uses carbon rather than water. A mixture of gases is heated to very high temperatures to produce carbon atoms in the form of a plasma. Out of the gases the diamond crystals can grow on complex, 3D shapes – such as tweeter domes

We bought 10.0 x 10.0 x 0.5 mm CVD diamond

1 for MSU and 1 for Winnipeg

PC-CVD diamond properties

	Silicon	Diamond
Band Gap (eV)	1.12	5.45
Electron/Hole mobility (cm^2/Vs)	1450/500	2200/1600
Saturation velocity (cm/s)	0.8×10^7	2×10^7
Breakdown field (V/m)	3×10^5	2.2×10^7
Dielectric Constant	11.9	5.7
Displacement energy (eV)	13-20	43
e-h creation energy (eV)	3.6	13
Av. e-h pairs per MIP per micron	89	36
Charge collection distance (micron)	full	~250

Low leakage current, shot nois

Fast signal collection

Low capacitance, noise

Rad hardness

Smaller signal

sc (single crystal) diamonds are available in sizes up to 8 mm x 8 mm x 0.5 mm
pc (polycrystalline) diamonds are available in huge wafers

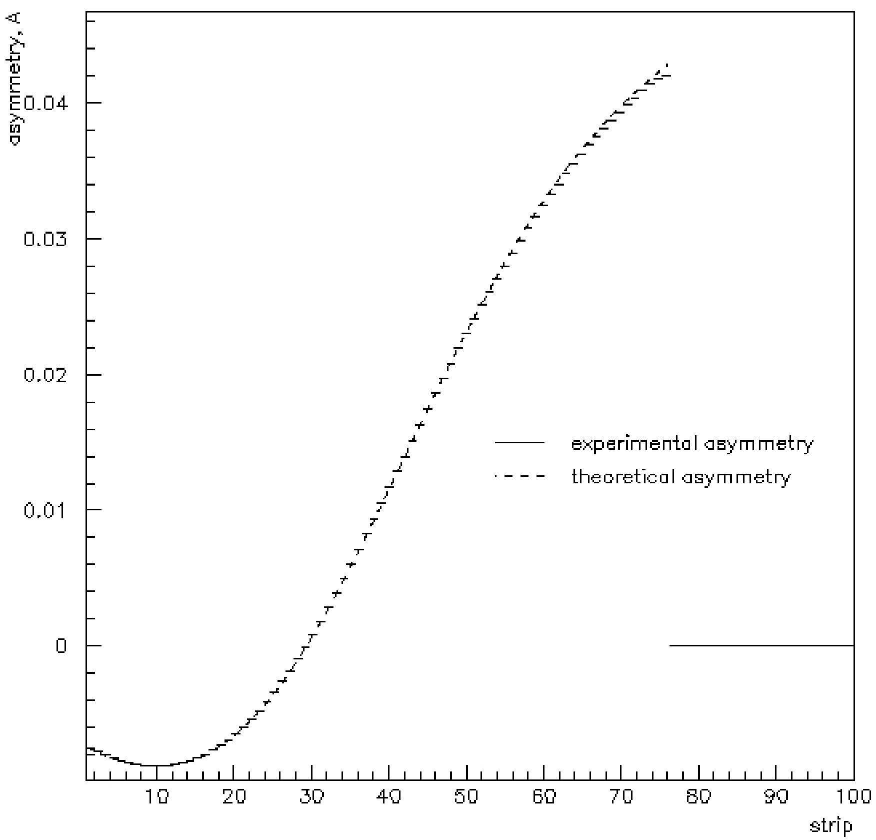
- we will use a 2 cm x 2 cm x 0.5 mm square pc-CVD diamond

Strip trackers have been developed by CERN RD-42 and others using that thickness, available from Element Six

Monte Carlo Electron Detector Simulation

- D. Storey, honours thesis, and continuing work through this Friday.

Asymmetry



- Measuring polarization by fitting the asymmetry function to the experimental asymmetry

$$A_{exp} = P_1 \frac{(1-((x-P_2)P_3)(1+a))\left(1-\frac{1}{(1-((x-P_2)P_3)(1-a))^2}\right)}{\left[\frac{((x-P_2)P_3)^2(1-a)^2}{1-((x-P_2)P_3)(1-a)} + 1 + \left(\frac{1-((x-P_2)P_3)(1+a)}{1-((x-P_2)P_3)(1-a)}\right)^2\right]}$$

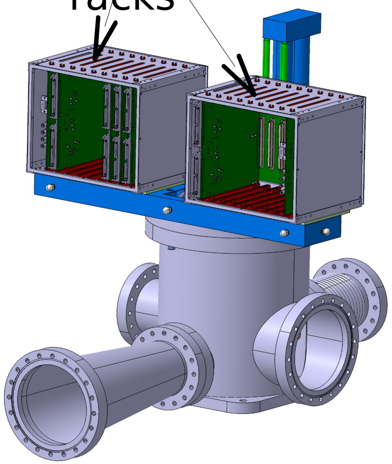
- P_1 is polarization
- P_2 and P_3 are energy calibration parameters of strip vs. momentum

Mechanics: look as Hall A did it

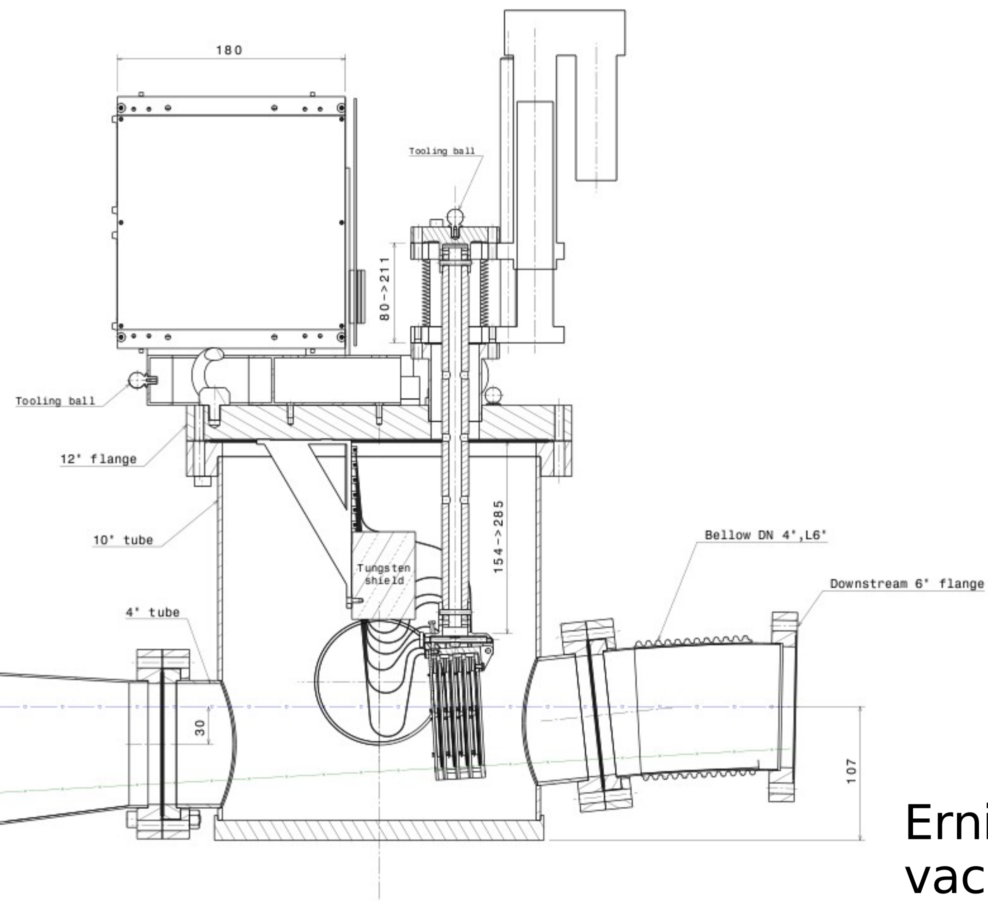
Mechanical design documentation courtesy Pierre Bertin

http://clrwww.in2p3.fr/meca/plans/Site-eb/Cebaf/TJN-DetE/TJN-DetE-P2.html

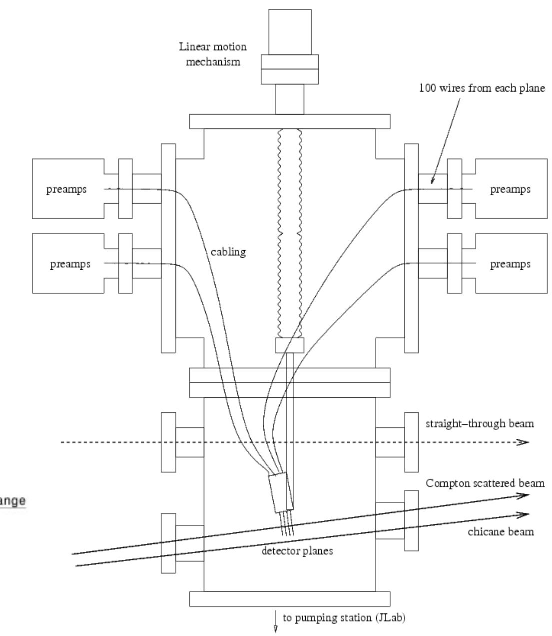
Front-end electronics racks



Hall A



Our design so far



Ernie Ihloff will help with vacuum chamber design (no instrumentation inside)

Electronics for e- detector

Front end board (pream-amp-discr. Chain) for 400 channels:

- We have access to full electronic circuit from Pierre Bertin (Clermont-Ferrand) Hall A Compton. Discussions ongoing with Pierre if C-F can fabricate for us modified frond-end board

- Enough alternate electronics exist at UWpg/MSState for tests:
  - UWinnipeg 32 channels
  - MSState 16 channels

Logic + hit map

- Hall A – Electron Trigger Read Out Card,

  Determine the coincidence between the four silicon microstrip detectors and to store the hit map.

http://hallaweb.jlab.org/compton/Documentation/Technical/flipsoft_doc/doc/hardware_papers/lpc_etroc/Etroc.pdf

- We can not get an old ETROC from Hall A
- We look at other possibilities: CAEN VME-V1495 under investigation

Hall C Compton laser to-do List

(Matt Poelker, 15 January, 2008)

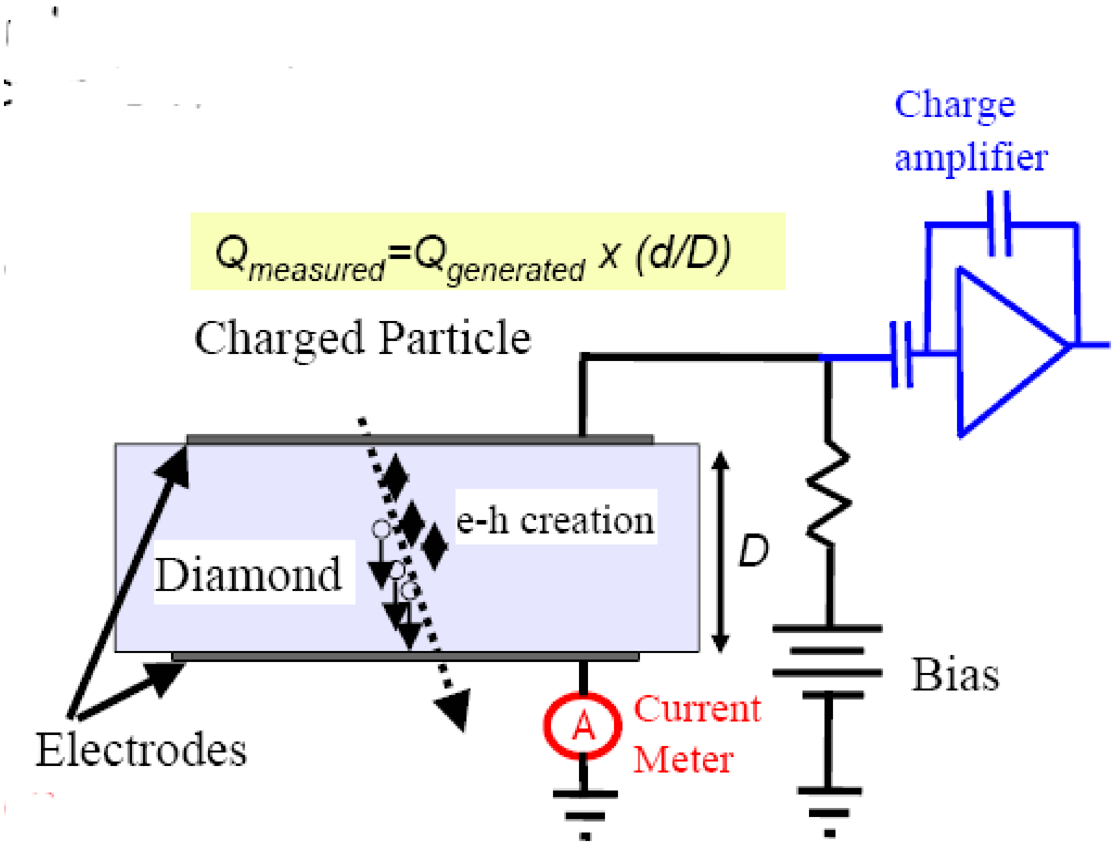
1. Identify Laser system Supervisor for Hall C
2. Find student (on the Compton LSS)
3. Characterize laser system, design external cavity amplifier system, finish a demonstration experiment in a lab
4. Purchase more seed lasers, find more with 20ns pulsewidth,
5. Purchase LBO frequency doubler, temperature controler, mirrors, lenses
6. Put seed light into 50W amplifier veryfy 50W output at 499MHz rep rate
7. Double this light and measure efficiency
8. characterize performance: phase noise and M2 value
9. Install prototype system inside Hall C transport line

Summary of Compton Polarimeter project

- Magnetic chicane:
- Laser beam:
- Photon detector:
- Electron detector:
  - Tests of diamond response to e- from ^{90}Sr underway
  - Prototyping mask done, work on photholitography underway
  - Electronics – discussion with C-F ongoing; for hit map we investigating if CAEN V-1495 is suitable
  - Mechanics: conceptual design, quotes for parts and fabrication exist.
  - Need to communicate need for vacuum chamber with Ernie Ihloff
  - Design of detector holder, inside instrumentation (TRIUMF, UW)
  - New grant submitted (will know answer on April 1)

Or previous page

How a diamond detector works



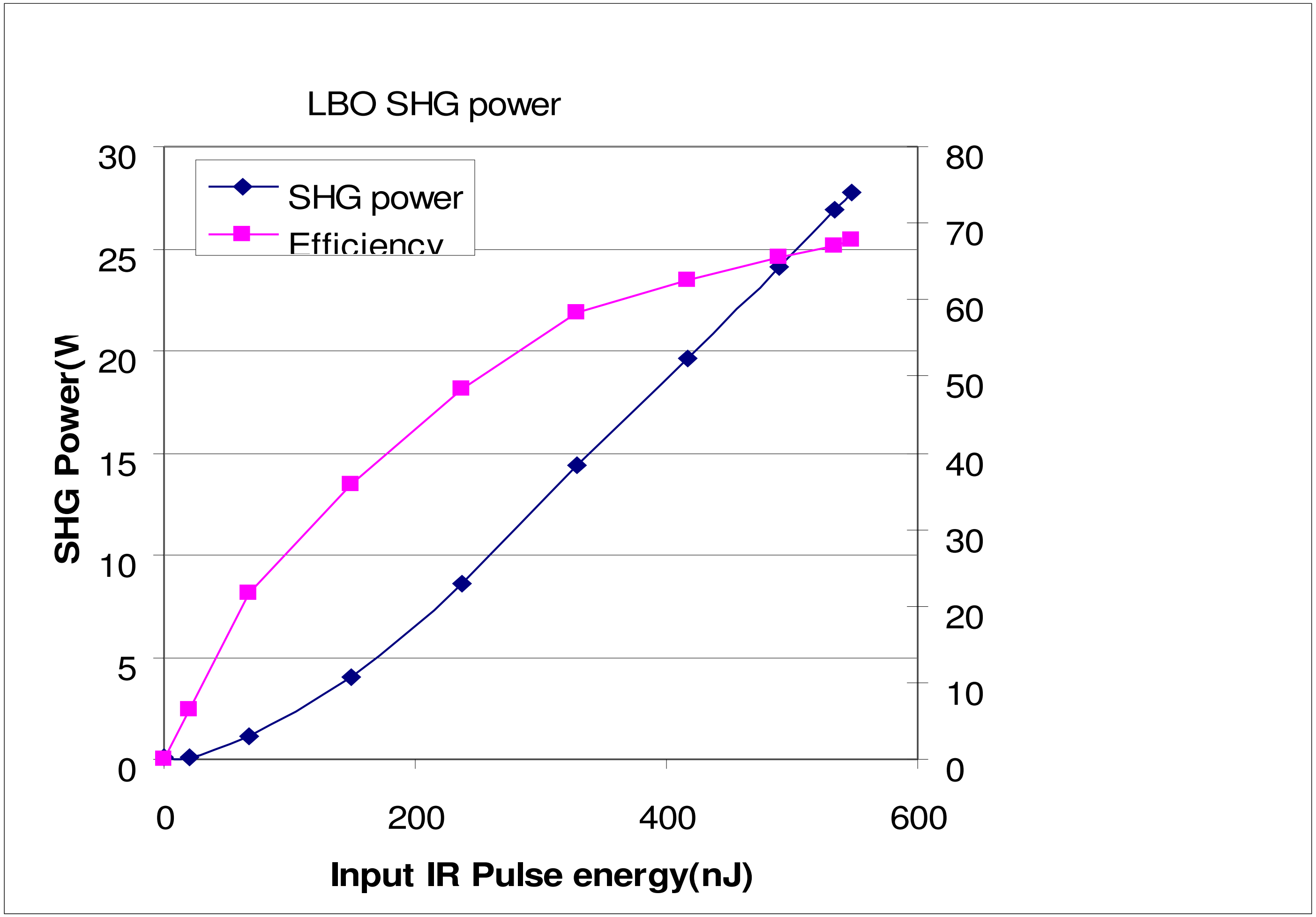
- Signal limited by impurities and grain boundaries
- Increases with E-field up to ~1-2 V/**μm**
- CCD (“charge collection distance”) ~ 250 **μm**

Diamond fabrication progress

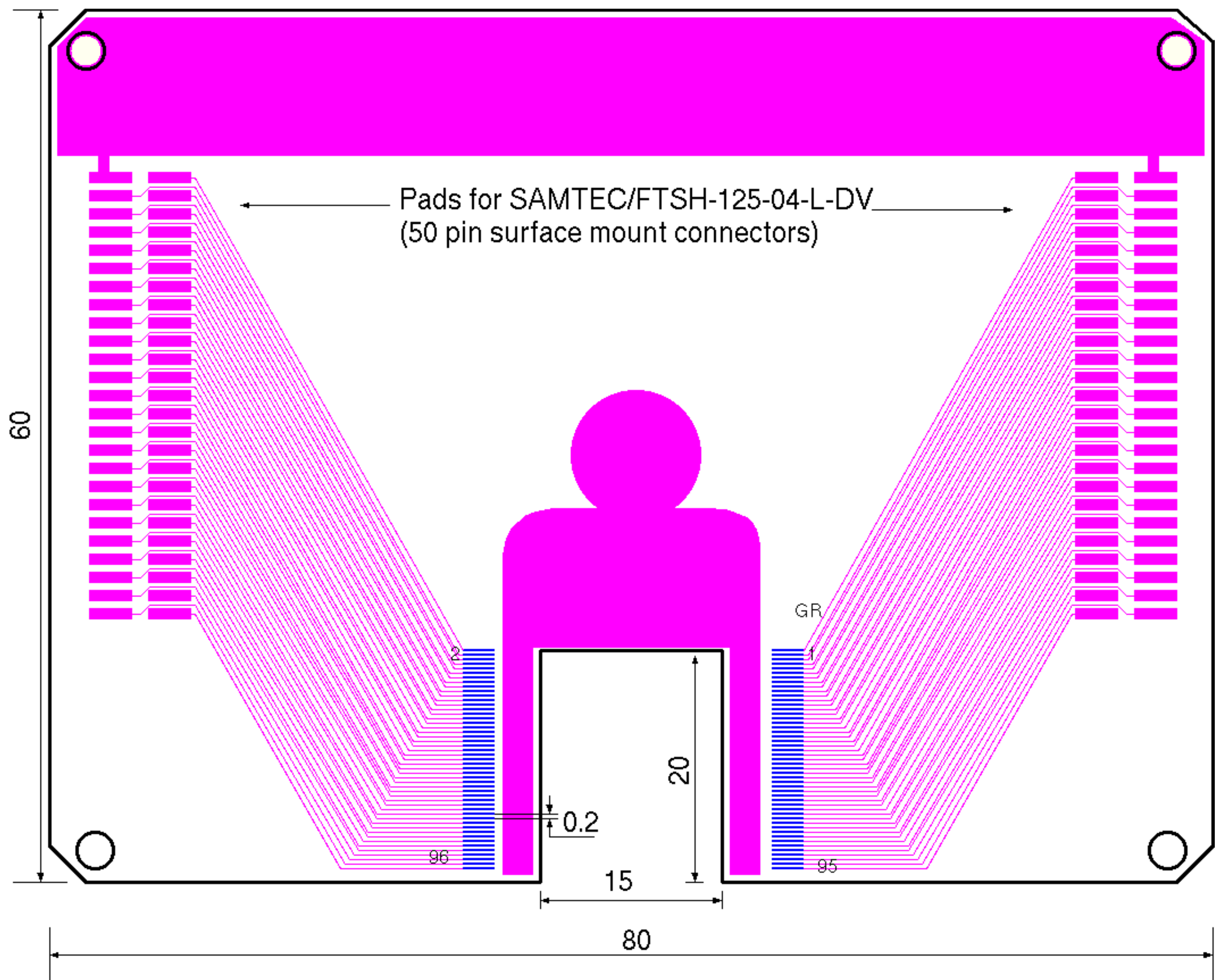
- Coated first test diamond at NSFL (UM EE)
- Visited OSU (Harris Kagan group)
  - learned diamond preparation/metallization in context of a second diamond (D. Dutta's)
  - learned multi-strip detector fabrication
  - learned test procedures (CCD measurement, I-V curve)
- Successfully fabricated our first working detector
- Tests of diamond response to e- undergoing
- Mask for photolithography done
- First attempt to coat diamond with strips (photolitography)

Estimated Attainable SHG Power

- IR50W/0.5GHz, 100nJ, 30% effi, 15W/SHG
- IR50W/1GHz, 50nJ, 14% effi, 7W/SHG



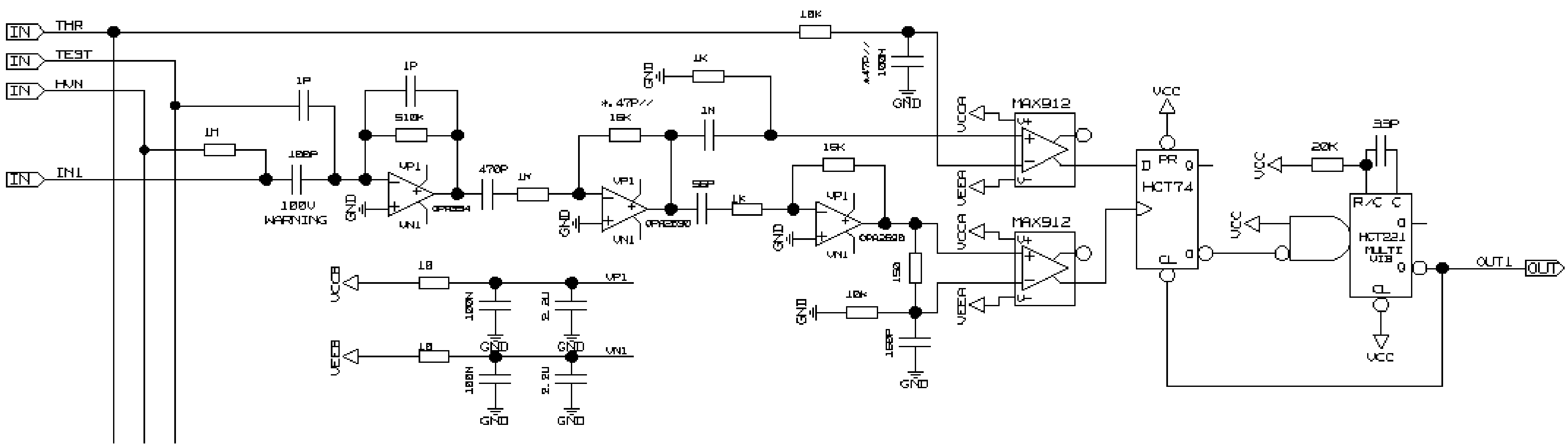
Carrier Board for Full Size



Electronics

Front end board (pream-amp-discr. Chain) for 400 channels:

- We have access to full electronic circuit from Pierre Bertin (Clermont-Ferrand) Hall A Compton. Discussions ongoing with Pierre if C-F can fabricate for us modified frond-end board



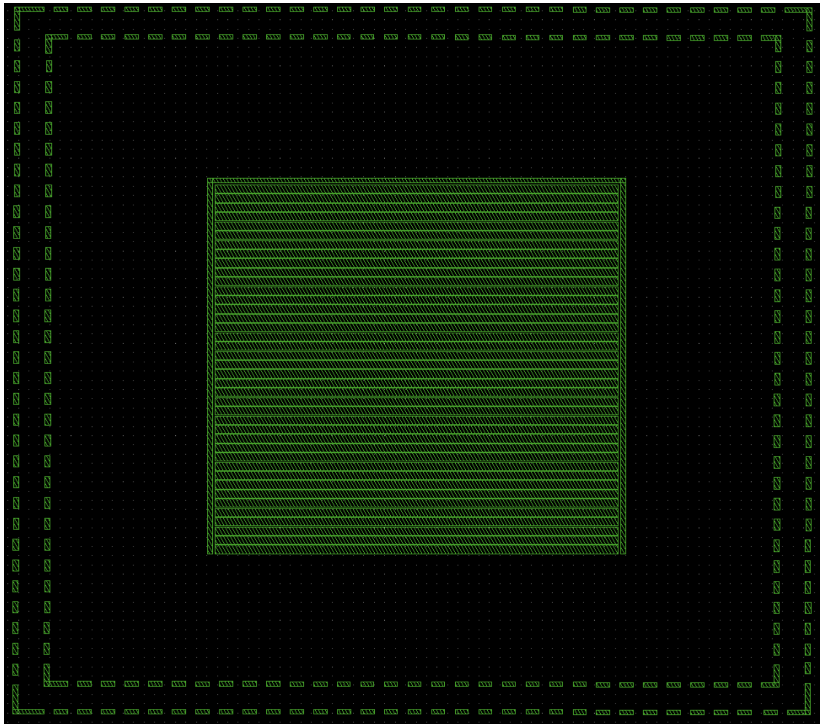
- Enough alternate electronics exist at UWpg/MSState for tests:
  - UWinnipeg 32 channels
  - MSState 16 channels

UW Mask design for “lift-off”

Mask 4 x 4 inch^2, drawing made using 'Layout' software

Has positive and negative images with patterns for 10 x 10 mm^2 test diamond sample and for 21 x 21 mm^2 sample

Fabricated at the University of Alberta,



Strip pitch :200um,
Strip width: 180 (150) um